WEST AFRICAN COCOA RESEARCH INSTITUTE

TAFO, GHANA.

SIXTIETH QUARTERLY REPORT

OCTOBER-DECEMBER, 1960

Any results recorded in this report should not be accepted as conclusive inasmuch as the report contains interim information only. More complete results are published in W.A.C.R.I. Technical Bulletins and elsewhere.

SENIOR STAFF

Director	J. Lamb
Secretary	A.F. Neale
Accountant	J.N.A. Hyde
Office Asst/Librarian	Mrs. D.J. Adams(Miss D.J. Ellis, on leave, resigned w.e.f. 7/10/60)

TAFO STATION

Division of Entomology	E. Dunn
	K.B. Armstrong
	M.R. Smith
	V. Ammah-Attoh
	B.M. Gerard (joined 22/11/60)
Division of Pathology	J.W. Blencowe (returned from leave 29/12/60)
	A.L. Wharton
	P.D. Turner
	A.A.F. Brunt (on leave 30/11/60)
	A. Attafuah (on scholarship in U.K.).
Division of Botany	D.R. Glendinning (returned from leave 11/10/60)
	R.G. Lockard
	E.J.A. Asomaning
Division of Chemistry	R.H. Kenten (on leave 24/11/60)
	D.K. Acquaye
Division of Agronomy	T.H.R. Hall (on leave 12/12/60)
	R.W. Smith
	M. Wessel (joined 31/12/60)
Statistician	C. de Jonge
Spectrographic Speclst.	J.C. Burridge
Laboratory Technician (Electronics)	A.J.H. Arnold (on leave prior to termination 30/11/60)
Plantation Manager	H.W.S. Allison
Maintenance Engineer	G.O. Hayward (on leave 5/10/60)
Asst. Maint. Engineer	G.O. Amponsah (appointed 20/12/60)
Works Superintendent	E.K. Berko
Guide-Demonstrator	F.E. Decker
Medical Officer	P.K.K. Knudsen

IBADAN STATION

Deputy Director	T.W. Tinsley (on leave 29/11/60)
Secretary	H.Ll. Pugh (returned from leave 12/10/60)
Entomologists	R.G. Donald (Ag. Deputy Director from 29/11/60)
	P.F. Entwistle
	C.K.H. Martini
Pathologist	D.Kay (on leave - engagement terminated 18/12/60)
Agronomists	J. Longworth
	G.H. Freeman
Mycologist	E.C. Hislop
Plantations Officer	W. Rides (returned from leave 14/10/60)

WEST AFRICAN FUNGICIDES RESEARCH UNIT

Chemist	P.O. Park.

STAFF MATTERS

Mr. D.R. Glendinning returned from leave on 11th October; while on leave he attended the VIIIth Inter-American Cocoa Conference at Port of Spain, Trinidad (15th to 25th June, 1960) and the cocoa Breeding seminar that preceded it. He also visited the Inter-American Institute of Agricultural Science at Turrialba in Costa Rica, to see the work on cocoa in progress there.

Messrs. H.Ll. Pugh and W. Rides returned from leave on 12th and 14th October, 1960, respectively.

Dr. T.W. Tinsley, Deputy Director, Ibadan Station went on leave on 29th November, 1960, and Mr. R.G. Donald took over as Acting Deputy Director.

Mr. G.O. Hayward went on leave on 5th October, 1960, Mr. R.H. Kenten on 29th November, Mr. A.A. Brunt on 30th November and Mr. T.H.R. Hall on 12th December, 1960.

Mr. A.J.H. Arnold left the Institute on 30th November, 1960, on leave prior to termination of secondment.

Mrs. D.J. Adams (Miss D.J. Ellis) resigned with effect from 7th October, 1960.

Mr. D. Kay's appointment terminated on 18th December, 1960.

Dr. W. Carter, of the Pineapple Research Institute, Hawaii was attached to the Institute throughout the quarter.

Dr. B.M. Gerard joined the Institute on 22nd November, 1960, as an Entomologist.

Mr. G.O. Amponsah, formerly a Senior Technical Assistant, was appointed Assistant Maintenance Engineer at Tafo on 20th December, 1960.

Mr. Lamb and Messrs. Dunn, Wharton, Glendinning and Arnold from Tafo visited the Ibadan Station during the quarter.

Mr. J.C. Burridge was placed temporarily in charge of the Electronic Workshop upon Mr. Arnold's return to Rothamsted at the end of November.

The Institute contributed an exhibit on cocoa research to the Federal Pavilion at the Nigerian Independence Exhibition held in Lagos, from the 1st to 22nd October, 1960.

An exhibit was displayed at the West African Science Association Conference held in Ibadan in December, at which Messrs. Longworth and Entwistle read papers.

VISITORS

Visitors to Tafo included Sn. T. Arviza, a Spanish Agronomist from Fernando Po, Mr. K.J. Bailey, Vice-Chairman of the Cocoa Association of London, two agronomists from Colombia,

M.L. Maire, Chairman of the F.A.O. Council, and other F.A.O. officials, a representative of the Bank of Ethiopia, two representatives of the Federal Reserve Bank of New York, representatives of commercial firms, visitors from the University Colleges of Ghana and Nigeria and Mr. Hilary Marquand, M.P.

Visitors to Ibadan included Viscount Head, U.K. High Commissioner in Lagos, Miss Dulles, personal representative of President Eisenhower, representatives of chocolate manufacturers, Mr. A.R. Lancaster of the Colonial Development Corporation and delegates from the F.A.O. Conference held in Lagos in November, 1960 and from the West African Science Association Conference held at Ibadan in December.

AGRONOMY AND PLANTATION MANAGEMENT DIVISIONS

OLD STATION FARM

Yield:

Three harvests were completed during the quarter from the 22-¼acre plots in the Old Station Farm. In Table 1 a comparison is made of the total yield in pods, where there is an increase of some 6 per cent over the previous quarter.

Table 1 : Pods from 22-¼acre Plots - Station Farm

Plots	Harvested	Diseased	Total
Tree recorded (5)	5,285	420	5,705
Plot recorded (17)	17,281	856	18,137
Total (22)	22,566	1,276	23,842
Sept. Quarter	20,386	2,022	22,408

The gross yields from the Old Station are given in Table 2.

Table 2

OLD STATION

October	20,046	3,892	-	-	103,831	127,769
November	6,421	13,809	-	-	96,445	116,675
December	13,568	5,150	-	-	39,331	58,049
Total	40,035	22,851	-	-	239,607	302,493

TREE MORTALITY

Losses of cocoa trees (Station Farm) due to swollen shoot infection and other causes are shown in the following table.

Table 3 : Tree Mortality

Month 1960	Trees destroyed		Total	Seedlings Removed	Grand Total
	Swollen Shoot	Undiagnosed			
October	52	7	59	11	70
November	25	6	31	19	50
December	20	1	21	14	35
Total	97+	14	111	44	155

+Including 25 contact trees removed.

SQUARE MILE

Routine harvesting occupied all personnel of the division during the quarter, but by the end of December, the bulk of the crop had been removed; the yields of experimental plots are given in Table 4, of commercial cocoa in Table 5.

Table 4 : Yields from Experimental plots - Square Mile.

No.	Experiment	Plot	December Quarter 1960
1.	U.A. Spacing and Pruning	B2	29,136
2.	U.A. " Extension	B2(a)	8,102
3.	U.A. Multiplication	B1	31,289
4.	Amelonado Spacing Trial	J1	119,923
5.	Factorial Fertilizer Trial	G5	23,385
6.	2nd Establishment Trial	H1 & L2	28,564
7.	Uniformity Trial	G1	76,031
8.	Amelonado Pruning Trial	P2	6,802
9.	" Source Trial	G4	9,241
10.	Shade & Manurial Trial	K1	57,244
11.	Amazon Tree Forming	D7	1,856
12.	Pathology Expt. Plot	A4	1,034
13.	" " "	A6	14,500
14.	" " "	H2	3,258
15.	" " "	H3	4,132
16.	Early Bearing Experiment	P1	15,593
-	T o t a l	-	430,090

Table 5.

	Young Planted Cocoa				Mature Cocoa	Total
	Amelonado	Amazon	Trini-tario	Hybrid		
October	21,508	-	249	52	99,243	121,052
November	61,476	-	304	173	67,743	129,696
December	9,381	34	38	-	39,525	48,978
Total	92,365	34	591	225	206,511	299,726

Routine maintenance of the young plantings, the seed garden and thinning trial, was carried out.

DISTRIBUTION OF PODS

Table 6

	Amazon F3
Western Region Nigeria Department of Agriculture	68,640
Northern Region Nigeria	2,840
Department of Agriculture Sierra Leone	1,000
Local Sales (W.A.C.R.I. Staff)	5,225

METEOROLOGY

Rainfall in inches and number of wet days for the quarter, compered with the past 22-year means are shown in Table 7.

Table 7

	1960		Past 22-year means	
	Rainfall(ins)	Wet days	Rainfall(ins)	Wet days
October	11.65	18	8.73	18.9
November	1.78	11	4.02	11.2
December	5.89	9	2.44	6.3
Total	19.32	38	15.19	36.4

PATHOLOGY DIVISION

BLACK POD DISEASE

MECHANISMS OF RESISTANCE AND TOLERANCE TO PHYTOPHTHORA PALMIVORA

Replicates of 10 unripe pods of selections from the 1st and 2nd Clonal Trials were wound inoculated with Phytophthora palmivora in the field and also incubated in humid chambers in the laboratory, and the lesion diameters measured after 4 days. Further replicates of 5 detached ripe pods were similarly inoculated. Mean length plus width lesion diameters are shown in Table 8.

Table 8.

	Selection	Unripe pods				Ripe pods	
		Field	Rank	Lab.	Rank	Lab.	Rank
1st Clonal Trial	S36	10.0±1.2	1	11.9±3.2	1	13.7±1.3	3
	E1	12.2±1.0	2	16.5±1.3	9	14.8±1.0	5
	K5	12.2±1.2	2	15.9±1.9	6	15.0±1.8	8
	ACu85	12.4±0.7	4	15.8±1.0	5	16.9±1.0	19
	B2	12.5±1.0	5	15.4±1.6	3	15.2±0.4	10
	A62	12.8±2.2	6	15.9±1.2	6	14.9±1.7	6
	A36	13.0±0.5	7	15.3±1.0	2	13.3±0.8	1
	SC1	13.1±1.2	8	16.6±1.4	10	14.9±0.8	6
	S27	13.1±1.0	8	15.7±1.4	4	13.4±1.4	2
	Y44	13.7±1.1	10	17.4±1.8	15	15.0±2.1	8
	N38	13.7±0.8	10	16.1±1.0	8	14.6±0.7	4
	S19	13.7±1.4	10	17.1±1.7	13	16.7±1.5	17
	A73	14.0±0.5	13	18.1±0.9	18	16.3±0.6	14
	B3	14.1±0.6	14	17.6±1.7	16	15.8±0.6	12
	E17	14.2±1.0	16	17.3±2.1	14	17.2±0.7	20
	A46	14.3±1.2	17	16.7±1.8	11	16.7±0.4	17
	U11	14.3±1.1	17	17.6±1.5	16	17.2±1.4	20
	E12	15.0±0.6	19	18.7±1.3	20	16.3±0.9	14
	A12	15.1±0.5	20	17.0±0.9	12	16.0±1.0	13
	O2	15.3±0.9	21	18.8±1.0	21	16.5±1.3	16
	Amelonado	14.1±1.0	14	18.1±2.0	18	15.5±0.2	11
2nd Clonal Trial	B1	12.5±1.6	2	15.2±1.6	1	14.1±2.3	6
	D70	12.6±1.2	3	15.3±1.8	2	12.9±0.3	1
	U6	12.6±1.5	3	15.7±0.6	3	13.3±1.0	3
	ICS1	11.0±1.1	1	15.8±2.0	4	15.3±1.0	13
	E1	13.5±1.4	10	16.1±1.5	5	15.2±1.3	12
	TF1	13.4±0.9	6	16.1±1.0	5	13.4±0.6	4
	W63	13.4±0.8	6	16.3±1.2	7	15.6±1.0	14
	C22	13.6±1.4	12	16.6±0.9	8	13.0±1.8	2
	S21	14.0±1.1	13	16.8±1.3	9	14.6±0.4	8
	O4	14.3±0.8	17	16.8±1.4	9	13.8±0.8	5
	D71	14.3±0.7	17	17.0±0.8	11	16.1±0.8	17
	ICS7	13.4±1.3	6	17.0±1.0	11	15.8±0.3	15
	R15	14.2±1.4	16	17.1±1.0	13	15.8±3.7	15
	A56	15.5±1.0	19	17.2±1.5	14	----	-
	TF2	13.0±0.8	5	17.3±0.7	15	----	-
	P30	13.5±0.8	10	17.3±1.2	15	14.7±1.0	9
	TF5	14.0±0.3	13	17.3±0.7	15	15.1±0.5	11
	E9	14.1±0.7	15	17.9±0.7	18	14.8±1.6	10
	W41	13.4±1.5	16	18.3±0.8	19	14.5±0.8	7

Table 8 Mean pod lesion sizes (length + width, cms.) 4 days after wound inoculation with P. palmivora of 1st and 2nd Clonal Trial selections.

Better correlation was found between field and laboratory results with selections from the 2nd Clonal Trial than with those of the 1st. Limited correlation also existed between selections showing a low incidence of disease and a lower rate of lesion development. It is evident, however, that post-penetration resistance or tolerance is not the only factor conferring resistance. The results also suggest that a change in susceptibility may occur with increasing age, and that tests on detached pods may give less reliable indications of resistance than field tests.

In a pilot experiment, extracts of external and internal endocarp tissues of single pods of selections showing a degree of field or laboratory 'resistance' (S27, ACu85, Y44, N38, B3, D70, D71, U6, P30 and E1) and others showing a high 'susceptibility' (A12, A62, A73, SC1, 02, R15, A56, TF2 and W41) were bioassayed on spore suspensions of P. palmivora. An intermediate selection (S21) and unselected Amelonado were also tested. Epidermal tissues of a standard maximum depth were removed by a commercial peeler, and care was taken to exclude mesocarp from the internal endocarp tissue slices. The pieces of tissue were soaked overnight in watch glasses, the tissue then removed, and sporangial suspensions obtained from pods added to the extracts. A control suspension was added to deionised water. The solutions were then transferred to a cooler temperature to promote and accelerate sporangial germination. After 3 hours further development was stopped by addition of mecuric chloride solution, and measurements were made of percentage sporangial and zoospore germination and of mean length of 20 zoospore germ tubes.

Epidermal extracts: Of the 'resistant' selections, complete inhibition of zoospore germination was found with extracts from unripe pods of ACu85, D71 and P30, and from ripe pods of ACu85, D70 and P30. Marked inhibition (LD.75) was also found with unripe pods of N38, D70 and U6, and with the ripe pod of S27. Low inhibitory rates (LD.50) were found with epidermal extracts of B3, S27, and E1 unripe pods, and with ripe pods of Y44, N33, B3, D71, U6 and E1. Extracts of unripe pods of ACu85, P30 and D71 also severely inhibited sporangial germination. On average, sporangial germination in epidermal extracts of unripe pods of 'resistant' types was 69% of the control, zoospore germination 24% and germ tube length 67%; mean values for ripe pod extracts were 104, 47 and 103% respectively. Epidermal extracts of unripe pods of 'susceptible' selections showed values which were, on average, approximately double those

of 'resistant' selections. However, marked inhibition (LD.75) of zoospore germination was found with the epidermal extracts of unripe pods of O2 and R15, and of ripe pods of A62, O2, R15 and W41. Mean sporangial germination in epidermal extracts of unripe pods of 'susceptible' types was 91% of the control, zoospore germination 52%, and germ tube length 119%; mean values of ripe pod extracts were 92, 56 and 102% respectively.

Internal endocarp extracts: Extracts of the internal endocarp tissue of some 'resistant' selections also showed inhibition of zoospore germination, although no extract produced complete inhibition. Marked inhibition (LD.75) was shown by extracts of unripe pods of B3, P30, D70 and ACu85, and of ripe pods of B3, D70, D71 and P30. On average, sporangial germination in extracts of unripe pods of 'resistant' types was 104% of the control, zoospore germination 47%, and germ tube length 103%; mean values of ripe pod extracts were, respectively, 96, 36 and 95%. Occasionally inhibition of zoospore germination was also found with tissue extracts of 'susceptible' selections, with ripe tissues of A73 and W41, and of the unripe pod of A12, showing most marked inhibition. Mean values for extracts of 'susceptible' selections were 89, 81 and 118% of the control for sporangial germination, zoospore germination and germ tube length respectively for unripe internal endocarp tissue, and 100, 62 and 135% for tissue from ripe pods.

It was apparent from the range of values obtained that ability to inhibit spore germination and subsequent development varied considerably, both between selections and between the different tissues of a single pod, and that a more critical examination of each selection is necessary. Data for each of 5 ripe and unripe pods of two selections, A12 and D70, showed little difference in inhibitory effects of extracts of any tissues, with the possible exception of the ripe D70 tissues. Further investigation of these and other selections are in progress.

In further tests with unselected Amelonado pods, aqueous extracts of mesocarp tissue showed very high inhibitory properties on addition of spore suspensions, suggesting that this tissue forms both a physical and chemical barrier to bean infection. In addition, bean pulp of both ripe and unripe pods was found to completely inhibit germination of both sporangia and zoospores.

Measurement was also made of the pH, water content and percentage dry weight of external and internal endocarp tissues from each selection used in the tissue extract spore tests, and analyses of the total nitrogen content of the same tissues were made by the Chemistry Division. No significant differences were found between the two groups of selections.

A GALL DISEASE OF COCOA IN GHANA

Results from a number of new experiments on the gall disorder of cocoa in Ghana are now available.

Using large one-year-old galls on seedlings as a source it has again been shown that they can carry infections inoculum superficially. Washings collected from these undamaged galls after spraying them with a fine mist of water are highly infectious in tests on cocoa half-beans (70 and 60 per cent infection in 2 experiments). Brushing similar galls and then test half-beans with a moist camel-hair brush gave 70 and 100 per cent infection in these experiments. The gall washings contained dense suspensions of fungus spores, most of which could be microspores of the Fusarium stage of Calonectria rigidiuscula (Berk. & Br.) Sacc. but this has not yet been confirmed. From these results it appeared that in early experiments, where mealybugs collected from field galls, or artificially colonised on seedlings source galls, transmitted the disease to test half-beans, the insects were probably carrying pathogenic inoculum on their bodies. However, more recently, high transmission rates have been obtained from mealybugs fed through membranes of sheep mesentery, from inside sterile tubes, on to nutrient agar cultures of an isolate of C. rigidiuscula which was known to induce galls in bean tests. The stylet canals of mealybugs are too narrow for even miscrospores of the Fusarium culture to enter and this experiment is being repeated before consideration is given to how the insects have picked up inoculum.

There now appears to be little doubt that a strain of C. rigidiuscula is responsible for the gall disease. Infective liquid cultures of gall tissue were prepared some months ago using a bacteriological medium. At the time it was considered that these mixed cultures probably contained a bacterial pathogen, but an infective culture of C. rigidiuscula was subsequently isolated from them (culture B 170). Further, streak dilutions from these cultures on to media containing Actidione, which suppressed the growth of the Calonectria, yielded only two bacteria which, as in all other tests of bacteria isolated from galls, were non-infectious to half-beans. More recently pure cultures of C. rigidiuscula have been collected from gall tissue by direct isolation methods. Using these isolates it is sufficient to test them on only 5 half-beans, by brushing on spore suspensions or mycelium, as galls are produced, almost invariably, on all the test seedlings. Galls can often be detected on the test plants only 12 days after inoculating and sowing the beans and subsequent growth of the galls

is prolific. Table 9 shows the highly infectious nature of one of these isolates (B151 - see Quarterly Report No.59) in one experiment using different methods if inoculating whole cocoa beans and half-beans. The fractions represent number of seeldings with galls over the total number of beans tested.

Table 9

A	Half-beans brushed with sterile water	0/10
B	Half-beans brushed with culture B151 with the same brush used for A	10/10
C	Half-beans dipped in sterile water	0/10
D	Half-beans dipped in culture B151	10/10
E	Whole beans brushed with sterile water	0/10
F	Whole beans brushed with culture B151 with the same brush used for E	5/8*
G	Whole beans dipped in sterile water	0/10
H	Whole beans dipped in culture B151	6/9*

*3 beans failed to germinate.

These infective isolates of C. rigidiuscula were isolated from discrete colonies on nutrient agar isolation plates and were considered to be free of contaminants. However, C. rigidiuscula is ubiquitous as a weak parasite on debilitated cocoa in Ghana, yet few trees have been found with galls. It was, therefore, considered necessary to apply further tests to these cultures to eliminate any possibility that they were in fact masking the presence of some other pathogen. Culture B151 was known to retain its infectivity after treatment with Aureomycin (cf. Quarterly Report No.59). A more stringent test was made on single spore cultures of this isolate. Once growth of a single spore could be detected visually it was immersed for 12 hours in a bactericidal solution containing Penicillin (50 units per ml.) Streptomycin (100 units per ml.) and Aureomycin (100 u gm. per ml.). Following this treatment the cultures continued to grow without any apparent ill-effects and when subsequently tested on 10 beans produced galls on all the seedlings. Using a sub-culture from this single spore isolate sterile half-beans were inoculated and grown in sterile sand culture. Twelve sterile beans grown in the same way but treated with serile water remained healthy but 15 of the 18 Calonectria inoculated seedlings threw typical galls. It is not, therefore, considered that the Calonectria provides points of entry, or is otherwise associated with, an undetected soil pathogen. Two further experiments have confirmed that

filtrates of liquid cultures passed through a Seitz filter are non-infectious suggesting that a virus is not associated with the cultures. As a further check, an aqueous spore suspension of culture B151 was diluted in 6 steps down to 1 part in 10^6 in a basal liquid medium. Samples from each grade of dilution were then tested immediately on 5 half-beans and subsequently at intervals of 1, 2, 4 and 8 days. Table 10 shows the results of the first experiment which is being repeated (fractions as for Table 9, the denominator is

Table 10

Dilution of Spore Suspension	Interval between infectivity tests (days)			
	0	1	4	8
1	5/5	5/5	5/5	5/5
1 : 10	4/4	5/5	4/4	5/5
1 : 10^2	4/5	5/5	4/4	5/5
1 : 10^3	1/5	4/5	4/4	3/3
1 : 10^4	0/5	0/5	4/4	4/4
1 : 10^5	0/5	0/5	5/5	5/5
1 : 10^6	0/5	0/5	4/4	5/5

reduced where half-beans failed to germinate). Beans tested on the second day originated from one pod and the growth of all was abortive due to a genetic abnormality. However, it can be seen from the table that the highest dilutions were originally non-infectious, due to a low concentration of inoculum, but as the few spores present grew into a mycelium infectivity returned after 4 days. This could not have occurred with a virus which may pesist, but not multiply, in vitro.

Two isolates of C. rigidiuscula from dieback areas on capsid blasted trees have been tested on beans by normal methods used with the Calonectria's isolated from galls. A total of 120 beans were tested with cultures of varying age but none produced galls. Material of the "cushion gall" disease from South American countries has been collected at the Commonwelath Mycological Institute and isolates of C. rigidiuscula recovered from these samples by Dr. C. Booth. It is hoped that during his U.K. leave period Mr. Brunt will have an opportunity to compare these isolates in bean tests with a comprehensive collection of cultures from Ghana.

Dr. W. Carter (USCM consultant) is co-operating on the mealybug transmission studies mentioned above.

ENTOMOLOGY DIVISION

LEPIDOPTERA STUDIES

LEAF EATING LEPIDOPTERA

Routine collecting and rearing of lepidopterous larvae found on cocoa is continuing.

NURSE SHADE V. NO SHADE EXPERIMENT

The larvae counts of Earias biplaga Wlk. were again higher on the trees in the unshaded plots (Table 11). These findings agree with the data collected during the two preceding quarters. The Earias population has been low during the period under review, but from previous records it can be expected to increase during the next few months.

Larvae of Prodenia litura F. were also commoner on unshaded trees during the quarter. Similarly larvae of Lophocrame phoenicochlora Hmps. were only found on unshaded trees, however, only small number of this species occur in the experimental area. Larvae of Casphalia flavicollis Wlk. were much more abundant than usual during the Quarter. Quite frequently more than thirty larvae occurred on a single small tree and consequently some trees were almost defoliated. However, since only a few trees were attacked by this species the average number of larvae per tree was less than two in all treatments. (Table 11).

The trees in the plots treated with insecticides (Quarterly Report No.59) appear to be in a better condition than those in the control plots. Data is being collected on the number of leaves, tree size, etc., but the results have not yet been analysed. Table 11 gives the average numbers of larvae per tree for several species found in each treatment during the quarter and indicates the relative effect of the insecticide on the species listed. The relative abundance of these species on shaded and on unshaded cocoa is also shown. Observations were carried out on 2844 trees (474 per treatment) during the period 4th October - 31st December, 1960.

Fertilizer was applied to each half plot in the first week of October, 1960 (see Quarterly Report No.59) but there have been no obvious effects so far.

Table 11

Effect of nurse shade and insecticides on the abundance of certain lepidopterous larvae per tree : October - December, 1960.

	SHADE				NO SHADE			
	Sevin	Dipte-rex	Cont-rol	All treat-ments	Sevin	Dipte-rex	Cont-rol	All treat-ments
Earias biplaga Wlk.	<0.01	0.01	0.02	0.01	0.09	0.10	0.25	0.15
Lophocrama phoenicoch-lara Hmps.	0	0	0	0	<0.01	0.01	0.02	0.01
Anomis leona Schaus	0.04	0.12	0.11	0.09	0.05	0.06	0.09	0.07
Prodenia litura F.	<0.01	0.02	<0.01	0.01	0.14	0.06	0.17	0.12
Characoma stictigra-pta Hmps.	0.01	0	0.02	0.01	<0.01	<0.01	0.02	0.01
Casphalia flavicol-lis Wlk.	0.01	0.07	0.23	0.11	0	0.03	1.12	0.38

CAPSID STUDIES

LABORATORY ASSESSMENT OF INSECTICIDES

Work on the persistence of chlorinated hydrocarbons on an inert substrate has been carried out and it is intended to follow this with further persistence studies in the field.

JOINT WACRI/DIVISION OF AGRICULTURE CAPSID CONTROL TRIALS

The Endrin and Sevin trials at Kwahu Tafo have been terminated having given evidence that Endrin sprayed 3 times per year November, March and July, at 1 oz. actual toxicant per acre will give very effective control of capsids on 2 acre plots. Results with Sevin at 1½ lb. actual toxicant per acre are disappointing. If costs of the insecticide become more economic, however, it is possible that a double application would result in a satisfactory control of capsids. These two insecticides have been replaced by Dipterex and Bayer S. 1752 which will be applied as a double spray with one month's interval.

MEALYBUG STUDIES

JOINT WACRI/DIVISION OF AGRICULTURE ANT/MEALYBUG CONTROL TRIALS.

Methods of application and Formulation Trials

Mealybug population has been at its highest for this year on all plots during the quarter with peaks in early September. Active nests of Crematogasterine and Pheidoline ants have also shown a gradual increase in number.

Surveys of Marmara gave evidence of a very high incidence of Marmara damage on pods in both treated and untreated plots. On twelve of the nineteen treated plots over eighty percent of pods sampled had more than sixty per cent of their surface damaged by Marmara. Determination of the degree of ripeness of pods is made very difficult under these conditions and in certain treated plots farmers have suffered heavy losses from black pod (Phytophthora palmivora Butl.) through leaving over ripe pods on the trees.

Further damage by Eulophonotus larvae has occurred on all treated plots and it has become evident that the expectation of the experiment, which was to minimise adverse secondary effects of heavy dosages of Dieldrin by different methods of application and formulation, is not being fulfilled.

Further work on potential formicides will now be followed using Heptachlor and Chlordane. Two 10 acre plots under the management of the Division of Agriculture at Nankese and Koransang have been set aside for this experiment. Further plots at W.A.C.R.I. will be used to supplement these two areas. The intention of the experiment is to achieve ant control comparable to that following Dieldrin spray with minimal build up of minor pest populations. Less emphasis will be placed on mealybug assessment and rather more on ant and minor pest population assessment in this experiment.

ANT/MEALYBUG POPULATION STUDIES

The survey of the various species of mealybugs and ants (see Quarterly Report No.59) is continuing.

POLLINATION STUDIES

It is proposed to study the effects of insecticides upon pollinating insects (especially Ceratopogonidae). Preliminary records will be started when a suitable site has been obtained.

INSECTICIDES

JOINT WACRI/DIVISION OF AGRICULTURE INSECTICIDE YIELD COMPARISON TRIAL

A small scale seedling trial, replicated as 5 x 5 Latin

Square, has been set up as a supplement to the larger yield trials in Eastern Region and Ashanti. There are nine seedlings per plot and examination will be made after six months to determine the effect of fortnightly insecticide sprays on the growth and development of the plants. A fertilizer trial with different levels of N and P has been superimposed on the Latin Square.

BOTANY DIVISION

PLANT BREEDING

Further confirmation of the relationship between yield and growth has been obtained from the 9th PTA, using a further year's data. (cf. Quarterly Reports 55 & 57 and Euphytica IX No.3 pp. 351-355, December 1960). The total yield obtained from trees up to March 1960 is positively correlated with their growth rate during the first three years after planting (1954-57) with $r = 0.802$. Total crop is slightly more closely correlated with the difference between this early growth-rate and that of the second three years (1957-60) with $r = 0.836$. The closest relationship between early growth rate and subsequent yield performance is the multiple correlation ($r = 0.945$) between total yield, stem diameter in November 1954 and the growth rate in the following three years.

Some preliminary studies have been made on the small trial planted in 1959 (Quarterly Report No.54 pp. 9-10) to find out whether in reciprocal crosses between Amazon and Amelonado parents, the progeny of either parent as female is consistently the more vigorous. (In the 9th PTA and elsewhere WAE is better than its reciprocal cross WEA 3.). The preliminary conclusion is that while greater seed weight of the progeny of the female Amazon parent gives an initial advantage to the seedlings that is still detectable after the lapse of 21 months, there is no evidence as yet of a difference in vegetative vigour between the particular reciprocal crosses in the present experiment.

In an experiment comparing hybrids between three Amazon parents and an Amelonado clone (P4/9:J114/5), there were no significant differences in growth rate up to June 1960. The three Amazon parents are Nanay 32, Parinari 35 and T63 (=Nanay 32 x Parinari 35); should the plants of Nanay 32 parentage continue to keep pace with those of T63 parentage, then Nanay 32 may be shown to be a valuable parent for hybridisation with Amelonado, especially as it is known to be resistant or tolerant to virus.

A similar series of experiments was started in Block M

in June 1960, consisting of :-

(1) An experiment similar to N13/3, but consisting of crosses of Na32 and of Pa35 to Amelonado clone P30, and of Na32 to Pa35.

(2) A number of crosses involving trees obtained in past attempts to cross Amazon cocoa by Theobroma grandiflora, and Amelonado clone P30. These trees show no signs of partial grandiflora parentage, but the segregation between individuals obtained from the same pod seems very wide. The present plantings are made to determine if any segregation takes place in these crosses to the vitually homozygous P30. It may be that the "Amazon x grandiflora" trees are homozygous, being derived apomictically from the female gametes of the Amazon parent in response to the presence of the grandiflora pollen. If this proves to be the case, a new technique of value in cocoa breeding may become available.

(3) A few seedlings obtained by open-pollination from a diploid/tetraploid chimera in the polyploid plot. These seedlings have not been individually checked, but one from the same pod proved to be tetraploid on examination, and it is hoped that some at least of these may be likewise.

The growth of the tetraploids in the tetraploid plot (Block N6 (part)) has been inferior to that of the chimeras, and these in turn inferior to the diploids. It is not certain however that the roots of any of these plants are tetraploid, and a fully tetraploid seedling may possibly grow better.

(4) The four putative "selfs" of Na32, together with some of the 'axil spot' seedlings from the same pod, have also been planted in the plot (Quarterly Report No.57 and Nature 187, 170, 1960).

Data from variety trials in Nigeria have been received and are being studied in conjunction with those from Ghana.

Reports on the quality of cocoa samples submitted to the British, American and Swiss manufacturers in March/April 1960 are now coming in but are still incomplete.

CHEMISTRY DIVISION

SOIL FERTILITY

FIELD EXPERIMENTS

Harvesting has been heavy on all the plots during the quarter, but by the end of December the bulk of the crop had been removed. The yields from the Amelonado Shade and Manurial

Trial (KI) had surpassed those of the previous season, and are shown below. Yields are quoted in lb. dry cocoa per acre, calculated on a basis of 12 pods per pound.

Shaded No Fertilizer	= 735 lb. per acre
Shaded + Fertilizer	= 1,007 lb. per acre
Unshaded No Fertilizer	= 2,433 " " "
Unshaded + Fertilizer	= 3,300 " " "

The figure of 3,300 lb. per acre is the highest yield recorded at W.A.C.R.I.

The percentage fertilizer response is the same on the shaded and unshaded cocoa, i.e. 36.3 per cent and 36.1 per cent respectively. This response is greater than the previous season, especially on the shaded cocoa. The high yield on the unshaded, unfertilized plots is somewhat surprising as the condition of the canopy suggested that this cocoa is declining in vigour. The difference between the shaded and unshaded cocoa is the greatest yet recorded, being 227.3 per cent increase due to shade removal on the fertilized cocoa and 227.7 per cent on unfertilized cocoa.

NEW EXPERIMENTS

Four individually-tree-recorded Amazon cocoa plots have been selected to continue the work on Nitrogen and Phosphorus responses. The proposed experiments will be conducted jointly by WACRI and the Cocoa Division of the Ghana Division of Agriculture. The plots are situated at Akaa (Volta Region), Kwadaso (Ashanti), Biene (Eastern Region) and Pankese (Eastern Region). A further plot at Goaso (Brong Ahafo) is being considered. It is expected to make the first applications on these plots in April/May 1961.

Irrigation:

The Pilot irrigation trial (H4(a)) was concluded at the end of the quarter. It has been in progress for two years covering the establishment period. The oscillating spray line is to be used for irrigation experiments in the nursery.

The irrigation trial on Mature Amelonado cocoa (KI) is being continued for a further year. The treatment has increased the yield of cocoa by approximately 20 per cent other than where the cocoa is unshaded and receives fertilizer. Here the response to irrigation has been approximately 7 per cent. This response on one third of the KI plot accounts, to some extent, for the high yields quoted above, but the figures have not yet been dealt with statistically.

Cover Crops:

The cocoa planted on the cover crops area (H5) has began

to yield, the yields being related to the growth data of the trees, and the cover crop used. The best treatments are those on the bare soil and Mulch plots where there is no competition, and the cocoa growing with natural regeneration is the worst.

LABORATORY STUDIES

Soil and Plant Analysis

The analysis of samples of mature leaves taken each month from the lower canopy of cocoa in the Shade and Manurial Experiment (Block K1) was continued. Soil and leaf analyses were carried out on WACRI Plot A6. These results confirmed that the necrotic symptoms which appeared on the plot in August-September (Quarterly Report 59) are associated with K. deficiency caused by the previous ground cover treatment.

During the period, eighty-four samples of plant material were analysed for total nitrogen for Pathology Division.

Studies were also commenced on soil phosphate in responding and non-responding cocoa soils to find out the difference in reaction of fertilizer phosphate on these soils. Data obtained so far show that over 50 per cent of the total phosphate in almost all the soils was in the organic form and did not succumb to mineralization on incubation for periods of up to 28 days at laboratory temperature and 50 per cent water holding capacity.

At Atwere and Nkawie, Ashanti, and WACRI Blocks H1 and L2 rock-and super-phosphate are being compared. Soil samples from these sites are being examined to find out the differences, and follow the changes, in the phosphate fractions. Leaf samples are also being analysed to find out the effect of these phosphates on the uptake of macro-and micro-nutrients.

SPECTROGRAPHIC STUDIES

Methods:

A spectrographic method has been developed for the determination of total SiO_2, Al_2O_3 and Fe_2O_3 expressed as a percentage of their sum, in ignited soils. Soil samples, finely ground in a mechanical agate mortar and then ignited, were diluted 10-fold with pure carbon powder in order to minimise matrix variations. Microphotometric measurements of the lines Si 2881.6, Al 3082.2 and Fe 3057.4 enabled the ratios Si/Al and Si/Fe to be determined. Analyses of 200 soil samples were made with the following standard errors for the mean of a pair of light intensity observations: 6.3 per cent for the ratio Si/Al and 5.3 per cent for the ratio Si/Fe. This information on major soil constituents has been obtained to provide a background for

subsequent trace element determinations.

Pot Experiment:

Good growth has been maintained in the pot experiment where changes in soil pH and manganese uptake are being studied. This experiment will be harvested in the first week of January 1961. A good growth response has again been obtained to the application of ammonium sulphate.

COCOA PREPARATION

The mechanical dryer came into operation and some twenty-five batches ($\frac{1}{2}$ - 1 ton dry cocoa) were processed. The results so far suggest that it will be possible to produce 1 ton dry cocoa every 24 hr. with a fuel consumption of less than 40 gallon diesel/ton.

With some of the batches the shell has been too brittle, possible due to slightly over-drying although the rate of drying may be the important factor.

Work on the factors during fermentation which affect the quality of the finished cocoa continues.

IBADAN STATION

VIRUS RESEARCH

VECTORS OF NIGERIAN COCOA VIRUSES:

The transmission of cocoa swollen shoot virus by aphids has been further studied. Plants infected by aphids have now been used as source plants in tests with aphids and mealybugs respectively and the first available results indicate that the transmissibility of virus from such source plants is unchanged for both species of insect.

Further tests on the transmission of cocoa necrosis virus were limited by a shortage of viable seed of Adansonia digitata L. Other plant species which are known to be alternative hosts of cocoa swollen shoot virus are now being tested for susceptibility to cocoa necrosis virus.

EXTRACTION AND PURIFICATION OF NIGERIAN COCOA VIRUSES FROM COCOA TISSUES:

Variations in the methods used to extract and purify viruses from cocoa tissues have been tried, but these have yielded no substantial increase in efficiency when compared with the methods previously reported.

THE EFFECT OF VIRUS UPON YIELD OF MATURE, RANDOMLY-PLANTED AMELONADO COCOA:

An experiment was laid down at Agodi in April 1959, on well maintained peasant farmers' cocoa. There were eight replications of three treatments :- healthy trees, trees inoculated

with virulent virus isolates, and with avirulent isolates. In four of the replicates virulent and avirulent isolates from Koroboto were used, and in the other four, avirulent Ikire virus, and severe virulent Offa-Igbo viruses were inoculated. The experimental plots were circular, of 22½ ft. radius, based on a central key tree; the number of trees per plot varied from 11 to 45. All trees within the virus plots were infected by grafting at least five infected bark patches onto each. One chupon was allowed to grow at the base of each tree to facilitate symptom observations. Eight months after inoculation the trees infected with different virus isolates had produced symptoms at different rates. Most symptoms were produced on trees infected with severe virulent Koroboto virus and, in general, virulent viruses produced symptoms earlier than avirulent ones. (see Table 12). There were no appreciable differences in yield between treatments in the first crop season when compared with mean yields of two pre-treatment years.

Table 12 : Symptom expression of different virus isolates in mature Amelonado cocoa; eight months after inoculation

Virus Isolate	Trees with symptoms per cent	Mean per cent for
Avirulent Ikire	24.7	(i) Avirulent viruses 45.4
Avirulent Koroboto	62.2	
Virulent Koroboto	43.6	(ii) Virulent viruses 63.6
Virulent Offa-Igbo	84.9	

THE EFFECT OF VIRUS UPON GROWTH AND YIELD OF DIFFERENT COCOA TYPES:

The 1956 variety trial at Gambari Experimental Station consists of five replicates of open-pollinated material of eight Amazon and Amelonado types. There are 15 trees per plot planted at 8 ft. by 8 ft. spacing. The cocoa is rather variable and there have been some deaths. In January 1961, six trees in each plot will be infected with a virulent virus isolate from Ikire, and six trees retained as healthy controls. Pre-treatment girth and yield data are available, and the experiment is designed to give more precise information on the effect of virus upon growth and yield of cocoa, and will give some indication of the reaction of different cocoa types to virus infection. In particular it will be of interest to observe the reaction of

more mature cocoa of Parinari, Nanay-Iquotos, and Scavina parentage to virus infection, and to determine to what degree the tolerance or susceptibility of the parent type is inherited in this open pollinated material.

VIRUS TOLERANCE STUDIES:

In the second virus tolerance field trial at Alakia (Alakia trial III), many of the inoculated seedlings are showing symptoms. In the Series II. varieties K(T63 x Trinitario) and E(T79 x E1 Trinitario) there was a 1 : 1 ratio of Parinari necrosis : Trinitario reaction, as did the latter variety in the first tolerance trial at Alakia (Alakia II.). However, in Alakia Trial III., Series II. Varieties A(T63 x Amelonado) and C(T63 x E1 Trinitario) have not yet produced Parinari necrotic symptoms, although variety II. A produced some necrotic symptoms in the first trial at Alakia, but there were not sufficient trees to confirm a 1 : 1 system of inheritance. Observations of symptom expression in later experiments are continuing.

NURSERY TRIALS

During the quarter a new nursery trial was started at Gambari. This continues the work done at Agodi in the two previous seasons (see Quarterly Reports 52 and 57 for descriptions of the treatments in these earlier trials). These previous trials had given slightly different results, and this was attributed to their having been planted at different times. It was therefore considered to be advisable to have different times of planting as one factor in the present trial, and seed is being sown at four-weekly intervals, starting in mid-November. Three shade treatments, heavy, light and none, form the main plots of the trial and are replicated twice. Sub-plot treatments, in addition to time of planting, are frequency of watering and type of pot. Water is being applied twice a week or every other day, and polythene pots are being compared with the more familiar whalehide pots. Each sub-plot of the trial has 24 plants, in four rows of six with a guard plant at each end of the rows, the four rows are in two pairs, with a gap of one foot between the pairs of rows. All material is open-pollinated T60, an Amazon selection, pods being collected from an area which includes only Amazon varieties. The trial will be planted in the field, and the effects of the nursery treatments on establishment will be noted. Polythene is much lighter and cheaper material than whalehide, and, if results are satisfactory, polythene will probably be used in our nurseries in future.

STATISTICS

The results of various past field trials were examined in more detail than had previously been possible, while a full analysis was carried out on the black-pod control trial just completed at Gambari. Trials were designed for other members of staff. Advice has also been given on statistical matters at the request of members of the Federal Department of Agricultural Research and the Research Division, Ministry of Agriculture and Natural Resources, Western Region, both of which have officers working on Moor Plantation.

PLOTS COMMITTEE

A plots committee was initiated during the quarter to ensure a propoer coordination of trial design, and land use.

BLACK POD STUDIES

LABORATORY STUDIES:

Several further fungicide formulations have been investigated for their efficacy in protecting detached cocoa pods against infection by Phytophthora palmivora (Butler) Butler, using the method described in the Annual Report 1959-60.

The general conclusions concerning the relative efficiency of cuprous oxides and copper oxychlorides has been maintained except that two copper oxychloride formulations containing a high proportion of near-colloidal particles were more efficient than other formulations of the same active ingredient. Further investigations confirmed that a captan and an organo-tin formulation protect pods from infection at low dosages, and show promise as alternatives to copper compounds.

FIELD INVESTIGATIONS:

The two field trials described in the Quarterly Progress Report 58 have been completed and the results analysed.

The results of the larger trial comparing 6 fungicides and control can be summarised as follows, in descending order of efficiency:-

Bordeaux mix. Cu_2O(i) Cu_2O(ii) COC+Ziram COC COC+Hg Control

The corresponding comparison in the laboratory assessment was :-

Bordeaux mix. Cu_2O(ii) Cu_2O(i) COC+Hg COC COC+Ziram Control

In the above summary

Cu_2O denotes cuprous oxide formulations.

COC, copper oxychloride formulations.

Hg indicates a small proportion of added organo-mercurial.

Under-lining of two or more formulations indicates that they do not differ significantly at 5% level.

In the second trial 1% carbide Bordeaux mixture applied at 3-weekly intervals was compared with 1% and 2% lime Bordeaux mixture applied at intervals of three and six weeks respectively and control. This trial was not entirely satisfactory due to poor yield, but the three treatments did not differ significantly from each other, though all were significantly better than the control.

Preliminary arrangements are being made for a field trial in the rainy season of 1961 in which 7 fungicides and a control will be compared.

ENTOMOLOTY

SHOT-HOLE BORER STUDIES

Laboratory studies on the effects of attack by shot hole borer, Xyleborus morstatti Hag., on cocoa seedlings grown under various controlled conditions of watering have continued (Quarterly Report No.59).

Studies on several aspects of the biology of adult beetles (mating behaviour, flight range and periodicity and the mode of transmission of the ambrosia fungus) have continued. Results will be reported later.

GAMBARI SHOT-HOLE BORER EXPERIMENT I.

An area of seedling cocoa planted was in June/July, 1960, to enable investigations to be made on the effects of shot hole borer attack on plants grown under several different cultural conditions. Each of sixteen plots has been divided into four sub-plots for the application of the following treatments:-

i Mulching (grass)
ii Mulching + watering (2 gallons/plant/week)
iii Weed regeneration
iv Weed regeneration + watering (as in ii. above).

Eight of the main plots have been shaded with cut palm fronds.

Monthly counts of borer incidence and measurements of seedling girth, height and leaf number are being made. Samples of soil are being taken for estimations of moisture content.

Up to the end of December, incidence of borers was highest in the shaded plots (87 attacks as compared with 11 in the unshaded plots) and beneath the shade was greatest on sub-plots with weed regeneration (56 attacks as compared with 31 in the mulched sub-plot). However, the general level of borer attack is low, only 6.7% of plants in the shaded plots and 0.9% of plants in the unshaded plots being affected. Further comments on the association of attack with such factors as growth and soil moisture must therefore be with-held until borer incidence has increased.

Araromi Shot-hole Borer Control Experiment:

In an area of seedling cocoa in which it was proposed to investigate several possible insecticidal methods of borer control (see Quarterly Report No.59), the first spray was applied early in November. As this trial was superimposed on one of an agronomic nature, a design was suggested by the Statistician which allowed the following eight treatments, each replicated nine times, to be applied without interfering with the results of the original trial:-

i. 0.5% dieldrin
ii. 1.0% dieldrin with added coumarone resin.
iii. 1.25% D.D.T.
iv. 1.0% endrin.
v. 1.0% "Sevin" (1-naphthyl N-methylcarbamate).
vi. 2.0% "Sevin"
vii. and viii. Unsprayed control plots.

Treatments i. to iv. inclusive, employ emulsifiable concentrates whilst treatments v. and vi. are with an 85% wettable powder. Spraying is being done at monthly intervals with pressure-retaining knapsack machines, and the stems of the seedlings are thoroughly wetted. The nature of the layout necessitated using plots of only twenty seedlings each; this is very small, but it is hoped that the relatively high degree of replication will give some compensation, allowing the detection of differences between treatments on which can be based further trials in the coming year.

The area is clean-weeded, the seedlings mulched and has a mixed shade cover, mostly of banana, tree-cassava and Gliricidia maculata.

At the end of December, borer populations were still low (12.5% of plants attacked) and no consistent differences could be detected between the treatments themselves or between treated plots in general and the control plots.

MINOR PESTS OF COCOA

The area of seedling cocoa planted at Gambari to observe the effects of cultural conditions on attack by shot hole borer (see above) is also yielding interesting data on the occurrence of several minor insect pests and a spider mite (Tetranychus sp. indet.).

At monthly intervals all lepidopterous larvae are being collected from the area and identified, as far as this is possible. It is not yet clear if lepidopterous populations in

General are most closely correlated with shade conditions or with the degree of leafiness and flushing, which varied greatly from one treatment to another. Table 13 compares the total numbers of larvae found with mean leaf numbers per seedling on four different treatments.

Table 13: Comparison of numbers of lepidopterous larvae with mean numbers of leaves on seedlings grown under four different treatments.

	SHADE		NO SHADE		SHADE + NO SHADE	
	Mean leaf numbers	Total Lepi-dopte-rous larvae	Mean leaf numbers	Total lepi-dopte-rous larvae	Mean leaf numbers	Total lepi-dopte-rous larvae
Weed Rege-neration	19.6	62	6.5	39	13.1	101
Mulching	21.0	72	9.9	51	15.5	123
Weed Rege-neration + Mulching	20.3	134	8.2	90	14.3	224

Due to the very mixed nature of the Lepidopterous populations, which in addition to the above mentioned species included Earias biplaga Wlk., Anomis leona Schaus., Prodenia litura F. and various Lymantriidae, Limacodidae, Geometridae and Psychidae, relatively low numbers of each species do not allow evaluation on a species basis; this will only be possible when further data are available. The area is receiving no insecticidal treatment.

Observations, which will be reported later, are also being made on the incidence of mealybugs, scale insects, Psyllids, aphids, thrips and spider mites.

SEKA.